

Role of fiber in poultry diets - Friend or foe?

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Introduction

Fiber sources have been traditionally associated in non-ruminant and human nutrition, with negative attributes, including a reduction in palatability and voluntary feed intake (FI), and a decrease in digestibility of most nutrients (Hamberg et al., 1989; Mateos et al., 2002; de Vries et al., 2012). However, most of these studies showing negative effects of fiber inclusion were conducted using high levels of fiber. Recent research conducted with broilers (Gonzalez-Alvarado et al., 2008; Amerah et al., 2009; Jimenez-Moreno et al., 2009a,c, 2013a), pullets (Guzmán et al., 2013a,b), turkeys (Sklan et al., 2003), and laying hens (Hetland et al., 2001, 2005) have shown that moderate amounts of selected fiber sources might benefit the development and function of the digestive tract and improve nutrient digestibility and performance. Moreover, the inclusion of extra fiber in the diets of pullets, laying hens, and broiler breeders reduces the incidence of cannibalism and mortality (Hartini et al., 2002; Mateos et al., 2012a, b; van Krimpen et al., 2009), improves animal welfare (Aerni et al., 2000; Hocking et al., 2004), and ameliorates the structure and consistency of the feces, with a lower incidence of dirty eggs (Pottguter, 2008; Amerah et al., 2009). Also, dietary fiber (DF) reduces ammonia emissions from laying hen manure (Roberts et al., 2006, 2007) and limits infective episodes by pathogens such as *Clostridium spp* (Kalmendal et al., 2011) and *Salmonella enteritidis* (McReynolds et al., 2006). Consequently, DF should be considered as a “nutrient” rather than as an “anti-nutritional factor” in animal feeding.

Role of dietary fiber in poultry diets

The fibrous fraction of the feeds encompasses a group of heterogeneous compounds differing in chemical composition and physical properties (Graham and Aman, 1991; Bach Knudsen, 2001). Dietary fiber is the most used term to define the fiber fraction of ingredients and feeds, and includes cell walls, stored non-starch polysaccharides (NSP), and lignin (Bach Knudsen, 2001). Based on their physico-chemical properties, DF can be divided into soluble and insoluble fractions with distinct effects on digestive physiology and animal metabolism. Consequently, the benefits of fiber inclusion in poultry diets will vary depending on factors such as characteristics of the fiber source, type of bird, and digestive health status.

Broilers, especially at young ages, require diets with high levels of crude protein, starch, and fat to meet needs for growth. However, the amount of fiber of these diets is limited and often, the physiological needs of the birds for structural components are not satisfied. When low crude fiber diets (< 3% CF) are fed, the development of the gastrointestinal tract (GIT), including the gizzard, is hindered resulting in reduced nutrient digestibility and poor feed efficiency (Mateos et al., 2012a, 2013; Verdal et al., 2013). Under these circumstances, the inclusion of moderate amounts of fiber might benefit GIT and gizzard development (Gonzalez-Alvarado et al., 2007; Sacranie et al., 2012). Also, the production of HCl, bile acids, and endogenous enzyme secretions is enhanced when low fiber diets are supplemented with adequate sources and amount of fiber (Rogel et al., 1987; Svihus, 2011; Sacranie et al., 2012). In addition to changes in the pH of the different digestive organs, DF also modifies the rate of feed passage of the digesta along the GIT, which might affect microbial growth and profile (Amerah et al., 2009; Perez et al., 2011; Rochell et al., 2012).

Data from different research centers indicate that the gizzard is the pace-maker of the GIT and acts as “the Director of the Orchestra” controlling the physiology, motility, and smooth work and functioning of the digestive tract. When the birds from a given flock show gizzards uniform in size and well developed, less digestive disturbances will occur, resulting in improved health status, productive performance, and wellbeing of the birds. Under practical conditions, feeding coarsely ground diets or including whole wheat or additional fiber to the diet will improve gizzard development. The mechanisms underlying the positive effects of these feeding

practices on bird performance are not fully understood, although it is believed that they stimulate gizzard activity and digestive secretions (Hetland et al., 2003). A well developed gizzard improves gut motility and may facilitate the release of cholecystokinin which in turn stimulates the secretion of pancreatic enzymes and gastro-duodenal refluxes (Duke, 1992; Amerah et al., 2009).

Dietary fiber and poultry performance

Numerous factors affect the response of avian species to the inclusion of fiber in the diet (Montagne et al., 2003; Mateos et al., 2002, 2012a). Some of these factors are related to the bird itself (i.e., species, age), some of them to the ingredient composition and nutritive value of the diet (i.e., nutrient density, fiber content, feed form), some to type (i.e. soluble vs. insoluble; lignin content; particle size) and level of fiber used, and some to the management of the birds and environmental conditions during rearing (i.e., hygiene of the barn, disease challenge, health status). Moreover, the numerous potential interactions (positives and negatives) among these factors modify the final effects as compared with effects when each of them is present alone. For example, a high level of fiber in the diet might be less adequate in healthy animals with high rate of growth than in animals challenged by the presence of microorganisms responsible for digestive disturbances (Berrocoso et al., 2013). Consequently, it is not easy to predict and give accurate recommendations on the level of “fiber” to be used in poultry diets. Factors with greater impact and interest are: a) type, particle size, and level of the fiber in the diet, b) target species and age of the bird, and c) management, hygiene conditions, and health status of the chickens.

a. Fiber type, particle size, and level of inclusion

Fiber sources differ widely on their metabolic and physiological effects in humans and animals. Depending on their properties, DF will show different fates and fermentation patterns along the GIT. The water soluble fraction of the fiber is viscous in nature and depending on the structure, porosity, and lignin content, will be fermented at different extent by the microbial population present in the crop and the large intestine. Therefore, soluble fiber sources, such as sugar beet pulp (SBP) might show a) increased digesta viscosity which may impair nutrient digestibility, b) higher water holding capacity (because of the high pectin contents and porosity), c) bulkier digesta

which may reduce FI (Guillon and Champ, 2000), and d) increased fermentation processes with production of volatile fatty acid (VFA). These VFA can be used as a direct source of energy by the mucosa cells. Also, VFA will reduce pH in the hindgut, helping in the control of microbial growth. On the other hand, insoluble fiber sources, such as oat hulls (OH) will show a) higher retention time in the gizzard (depending on particle size) which might affect FI, b) increased rate of passage in the distal part of the GIT where it will be hardly fermented, and c) abrasion of the wall of the GIT which might affect mucine and mucosa integrity and increase endogenous nutrient losses. However, DF might also improve the tonicity of the walls, defending the digestive mucosa against the adherence of potential pathogens present in the digesta. Interestingly, Jimenez-Moreno et al. (2009b) reported an improvement in ileal digestibility of most nutrients in broilers when 30 g OH/kg were added to the diet whereas no positive effects were observed for SBP. Also, Gonzalez-Alvarado et al. (2010) reported higher FI in broilers fed 30 g OH/kg than in broilers fed 30 g SBP/kg. The authors suggested that the reduction in FI in birds fed SBP was due to higher water retention that increased the bulkiness of the digesta content and the feeling of satiety of the birds. Recently, Jimenez-Moreno et al. (unpublished data) studied the effects of including 2.5% or 5.0% of 3 insoluble fiber sources (rice hulls, SFH, and OH) in broilers feeds presented as mash or pellets at expense (wt:wt) of the control diet on performance from 0 to 21 d of age. The data showed that the inclusion of insoluble fiber in a low fiber diet improved ADG and F:G of the chicks but no differences among insoluble fiber sources were detected (Table 1).

Particle size influences the fate of different events occurring in the digestive tract of broilers such as transit time, fermentation capability, and adherence to bile, microorganisms, and certain digestive and dietary components. Fiber structure and size also plays an important role on the physiology and development of the gizzard and the GIT. Particle size (and available surface) of the fiber sources depend on the nature, the grinding process (e.g. roller mills vs. hammer mills), and feed form (mash vs. pellets). The mean particle size and particle uniformity of different fiber sources will vary even when ground using a common mill with the same screen size. For example, OH particles are fusiform and quite flexible whereas SBP are round and break easily when friction and pressure are applied (Mateos et al., 2012a). Therefore, the mean particle size will be higher for OH than for SBP because a higher percentage

of OH particles will pass unchanged through the screen. Consequently, OH will be coarser than SBP, in spite of both fibers being ground under similar conditions. In addition, particle size of the fiber sources varies during the transit in the GIT, as a result of gizzard mechanical action and bacterial degradation in the large intestine. Therefore, the mean particle size of a fiber source before ingestion is not necessarily relevant to assess its effects on GIT physiology.

Table 1. Main effect¹ of inclusion (wt:wt) of insoluble fiber sources on growth performance of broilers fed mash or pellet diets from 0 to 21 d of age (Jimenez-Moreno et al., unpublished data)

Type	Level (%)	ADG (g)	ADFI (g)	F:G (g/g)
Control	-	33.0	41.9	1.272
Oat hulls	2.5	34.1	42.9	1.259
Oat hulls	5.0	33.8	42.2	1.255
Rice hulls	2.5	34.2	42.8	1.255
Rice hulls	5.0	34.7	43.9	1.265
SF hulls	2.5	33.8	42.1	1.248
SF hulls	5.0	33.7	42.2	1.254
SEM (n = 14)		0.48	0.58	0.006
Probability				
Control vs. all fiber diets		*	NS	*
Fiber source		NS	NS	NS
Fiber level		NS	NS	NS

¹Average of feeds presented as mash or pellets.

Jimenez-Moreno et al. (2010) compared the effects of including 30 g/kg of diet of microcrystalline cellulose, OH, or SBP. Cellulose inclusion had little effect on gizzard development or broiler growth, probably because this fiber source lacks of physical structure and does not affect the anatomy or the physiology of the GIT. The inclusion of SBP improved energy retention but had no effects on ADG, probably because of the decrease in FI observed. In contrast, OH an insoluble NSP source, improved energy digestibility and ADG of the birds. The results of these trials highlight the different response of growing birds to fiber sources differing in physico-chemical characteristics.

Level of inclusion affects the response of poultry to DF with more positive effects in diets with low fiber content and more debatable effects at moderate or high levels of fiber inclusion. An increase in DF, especially of the soluble fraction, results in bulkier digesta that can induce satiety and reduce FI. Modern broilers are characterized by their voracity and extremely high rates of growth, which requires fine tuning in the design and manufacturing of the feed. In fact, poultry diets are formulated not only to meet nutrient requirements but also to favor voluntary FI of the birds. When fiber is added to the diet, energy intake might decrease in growing birds because of poor palatability or limited capacity of the GIT at this age. Jimenez-Moreno et al. (2011, 2013a, b) studied in 3 experiments the effects of including 25, 50, and 75 g/kg of pea hulls, OH, or SBP at expenses of the control diet (wt:wt) on digestive organ size, nutrient digestibility, and broiler performance from 1 to 21 d of age. The results of these trials confirmed the positive effects of including pea hulls or OH in the diet at levels of up to 50 g/kg on most of the variable studied, including gizzard weight, gizzard pH, and growth rate. However, a further increase to 75 g/kg had no further effects on organ development and gizzard pH and in fact, reduced nutrient digestibility and growth performance of the birds. The inclusion of 25 g/kg SBP in this control diet also improved the traits studied but the effects were less pronounced than when OH or pea hulls were used. Moreover, SBP inclusion at levels of 50 g/kg, already affected FI and growth of the birds. SBP is rich in pectin, a soluble fraction of DF that increases bulkiness and viscosity of the digesta and hinder the diffusion and absorption of nutrients in the small intestine. Consequently, an excess of dietary pectin might reduce FI and nutrient utilization at a higher extent than and excess of insoluble fiber. All these data confirm that broilers fed low fiber diets

benefits from additional fiber but that an excess might not be recommended. The level of fiber to be used in poultry diets will depend on the age of the bird as well as on the type of fiber used.

b. Target species and age of the bird

Numerous studies have demonstrated the effects of DF on different aspects of broiler and laying hen production, but the information available in pullets is scarce and more elusive. In fact, few papers have been published in recent years on the potential benefits of DF on pullet performance and subsequent egg production during the laying cycle. Guzmán et al. (2013b) included 2 or 4% straw, SFM, or SBP at the expense (wt:wt) of the control diet in pullets from 0 to 5 wk of age and reported higher ADG but similar F:G ratios when the insoluble fiber sources were added (Table 2). However, pullets fed SBP tended to grow less than pullets fed SFH, although the differences did not reach significance. In a recent research (Kimiaetalab et al., unpublished) we compared the pH in the different organs of the GIT of broilers and pullets from 1 to 21 d of age fed commercial diets with or without an additional fiber source. The treatments were organized as a 2 x 2 x 2 factorial with 2 type of birds (broiler vs. pullets), 2 type of diets (commercial starter diet for broilers vs. commercial starter diet for pullets), and 2 levels of SFH in the diets [0 vs. 30 g/kg in substitution (wt:wt) of the control diet]. Results obtained for selected digestive organs and main effects at 21 d of age are shown in Table 3. Pullets had higher crop pH (4.71 vs. 4.51; $P < 0.001$) and lower gizzard (2.20 vs. 2.43; $P < 0.05$), ileum (6.59 vs. 6.79; $P < 0.10$), and cecum (5.72 vs. 6.12; $P < 0.001$) pH than broilers (Table 3). Also, the inclusion of SFH to the diet reduced gizzard pH (2.20 vs. 2.43; $P < 0.05$) but had little effect on the pH of the other organs.